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A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture.

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In This Issue

Cover

The whitebark pine ecosystems of the West are important habitat for a variety of wildlife, including grizzly bears who find the trees' oil-rich seeds an important source of food. In some areas, however, whitebark pine populations are declining so rapidly that the ability of the tree to regenerate itself is in question. Details begin on page 5.

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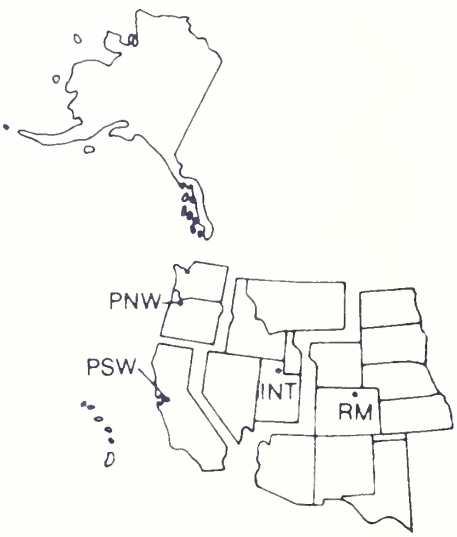


The ecology of what deer eat

by Cynthia Miner
Pacific Northwest Station

As autumn approaches, the Sitka black-tailed deer saunters under spruce, hemlock, and cedar and forages on Alaska blueberry, bunchberry dogwood, and trailing bramble. In the deer's range of southeastern Alaska and coastal British Columbia, resource managers face questions about the deer in context of old-growth versus even-aged forests and what can be done to improve even-aged forests as wildlife habitat.

Researchers from the Pacific Northwest Station, Arizona State University, Oregon State University, University of Alaska, University of New Mexico, and Washington State University addressed the concerns of Alaska resource managers by asking, "How much better is one habitat than another?" The results from six years of research examining the deer and its ecology have implications, however, beyond the Sitka black-tailed deer and its range. These implications are critical to assumptions resource managers make as they manipulate habitat for deer in most of the United States and in Canada.

Toward a broad understanding

The Sitka black-tailed deer was the focus of about 30 studies in this major research project. Scientists first worked, however, toward understanding the physiology of deer in a general sense and then applied that understanding specifically to Sitka black-tailed deer in southeastern Alaska. "We asked, how do deer respond physiologically to their environment?" said Tom Hanley, research wildlife biologist, Pacific Northwest Station.

Deer wearing a gas mask for measuring oxygen consumption (for calculating energy expenditure) during locomotion in snow.

To gain broad knowledge, the researchers studied mule deer and elk as well as black-tailed deer in southeastern Alaska, eastern Washington, and Yellowstone National Park in Wyoming. The energy cost of locomotion through snow, for example, is the same whether in Alaska or in any other area with snow. The researchers also compared their results with studies of white-tailed deer and other species whenever possible. The comparative studies allowed the researchers to derive general relations that apply across species and to gain greater understanding of how black-tailed deer differ from other species.

Vegetation is sampled for measures of availability and chemical composition.

Nutrition

Although the nutritional requirements of domestic animals have been well-studied, much less research has been done on the nutritional ecology of wild animals. "Food is ultimately what limits the productivity of herbivores," Hanley explains. "It's not just quantity of food, but a combination of quantity, quality, and the cost of getting the food."

Hanley and the other researchers in the effort examined the following intricacies of nutritional ecology: overstory and understory relations, influence of overstory on snow depth and density, forage availability and quality, diet composition and energy intake, and energy expenditure. These combined factors indicate how efficiently an animal can meet its daily foraging needs. Foraging efficiency was a critical aspect of the research.

Foraging efficiency

Foraging efficiency is the difference between energy taken in and energy expended by a deer searching for and consuming food. This efficiency is influenced by (1) the amount and quality of understory vegetation used as food, and (2) the depth and density of snow as it affects vegetation availability and deer mobility. Forest management influences deer by altering the forest overstory, which in turn affects understory production and, ultimately, foraging efficiency.

With increased foraging efficiency, deer accumulate more body reserves, spend less time foraging, or both. As a result, deer are in better condition, have better reproductive performance, and live longer. Also, the less time a deer needs for foraging, the more time the animal can rest, stay alert for predators, and engage in other activities. By influencing habitat selection and the well-being of individual deer, foraging efficiency is important in determining the carrying capacities of habitats for deer populations.

Tools for managers

A model was developed as part of the research project to evaluate the process of foraging efficiency. The model calculates the grazing time an animal needs to meet its daily energy costs. Inputs for the model include animal species (thus, species other than Sitka black-tailed deer can be used), body weight, snow depth, snow density, forage type, selected biomass, and digestibility. The model is described in General Technical Report PNW-230.

A method for estimating carrying capacity based on available forage meeting specified nutritional constraints was also developed in the deer research effort. The user specifies biomass and digestibility of available foods and nutritional requirements of the animal species. The method and an example of its use are described in Research Note PNW-485.

Major findings

Results from the research effort provide an array of detailed information, most of it closely connected to nutritional ecology. Hanley identified three major findings of the research project: (1) food quantity means more to deer populations than to individual deer, which are more dependent on factors such as leaf size; (2) in winter, energy balance of deer is more strongly controlled by food than by cold or traveling through snow; and (3) variety in landscape is important to deer throughout the year because both the habitat and the metabolic needs of the deer change seasonally. In southeastern Alaska, old growth is important in providing such variety.

Food quantity, quality, and size

Hanley was most surprised to find that the bite size of food is critical to a foraging animal. "I had underestimated the importance of the size of the package that the food comes in," he said. The speed at which an individual animal can eat is largely determined by the bite size. For the individual deer, factors like leaf size become more critical than how much food is available. Habitat choices, by deer, therefore, should be based more on the quality and sizes of food items than on their quantity. Populations of deer, on the other hand, greatly depend on quantity of food—the quantity of food that is of adequate quality and size.

Energy balance

The scientists found that deer experience different energy costs of foraging in different habitats depending on slope steepness, snow depth, obstacles, thermal characteristics of the habitat, and rate of travel by the deer. The energy cost of locomotion through snow increases exponentially with deeper snow and denser snow. Energy costs of locomotion vary with the animal's body weight, direction of movement on the slope, and speed of travel. Energy expenditure is also affected by the thermal environment (determined by solar radiation, wind speed, rain, and ambient air temperature).

Energy balance is more sensitive, however, to changes in food supplies (which affect energy intake) than to energy costs. This is because at least half of a deer's energy requirement is needed simply to maintain normal body function (the cost of lying down in a thermally comfortable room). Changes in activity costs are dampened relative to the total energy budget. The deer's entire energy intake, on the other hand, must come from its daily consumption of food, which can vary greatly in concentration of digestible energy. Deer cannot compensate for low-quality food simply by eating more.

Landscapes

In southeastern Alaska, habitat protection is the most important aspect of habitat planning for deer. Emphasis in deer management has been on minimizing winter mortality of deer. The focus has been on low-elevation old-growth forests as critical winter range. The researchers found that these habitats are most important where summer range is not of sufficient quality for high rates of reproduction, where wolves coexist with deer, and where winter snow accumulations are frequent and persistent. When these three factors are absent, however, critical winter range is less important.

The researchers suggest that although winter range is important, greater attention needs to be paid to summer range than in the past. The quality of summer range influences how well deer reproduce and store reserves as they enter winter. But more important than summer range conditions is the relation between the carrying capacities of summer and winter ranges. The population will be limited by whichever carrying capacity is lowest. Winter ranges for deer coming from highly productive summer ranges therefore need priority over other winter ranges. Similarly, summer ranges for deer coming from high-quality winter ranges should receive priority over other summer ranges.

The researchers also found that clearcut logging of old-growth forests in southeastern Alaska decreases carrying capacity of deer habitat in four ways: (1) sun-grown plants in open clearcuts have lower digestible protein concentrations than do shade-grown plants in forests; (2) large amounts of logging slash increase energy costs of locomotion for deer and reduce the area of usable habitat; (3) snow accumulates and persists more in open clearcuts than in forests; and (4) understory production is greatly reduced when the conifer canopy closes at about age 20 to 30 years and remains extremely low for at least the next 100 years. Clearcuts increase carrying capacity in one way: understory production is extremely great during the first 20 or 30 years after the cut. The challenge for forest managers, therefore, is in decreasing the negative effects and increasing the positive effect of logging.

Hanley and other researchers advise managers to plan for a continuous mix of open clearcuts and forests as they manage even-aged stands for deer habitat. Small clearcuts and a mixture of many different ages are desirable. Noncommercial old-growth and commercial stands retained for habitat protection are also important for habitat diversity. And, landscape diversity must exist within the size of average seasonal home ranges of deer, about 250 acres.

A chemically labled marker is injected into a deer's rumen during studies of digestion and food passage.

Research continues

Although breakthroughs have been made in understanding the physiology and ecology of deer, scientists in southeastern Alaska are now field testing conclusions from their many separate, controlled experiments. Hanley says, "Essentially, we're asking: Do we really know what we think we know? Do deer integrate all these separate relations in the way we think they do?" The foraging ecology and energy balance of 10 tame but free-ranging deer on a 250-acre island are being studied for 28 months to see if behavior and physiological performance match predictions. At the Pacific Northwest Station's deer research facility in Juneau, Alaska, 17 other deer are being studied in experiments on the roles of phenolic compounds in natural forages in digestion, food intake, and diet choice.

For a more detailed research synthesis and further information on the model mentioned above (see "Tools for Managers") request *Forest Habitats and the Nutritional Ecology of Sitka Black-Tailed Deer: A Research Synthesis with Implications for Forest Management*, General Technical Report PNW-230, from the Pacific Northwest Station. The reference section of this general technical report lists associated scientists and articles describing specific portions of the research effort. For more information on the method for estimating carrying capacity, request *Estimating Carrying Capacity with Simultaneous Nutritional Constraints,* General Technical Report PNW-485.

Whitebark pine ecosystems: the threats and the challenge

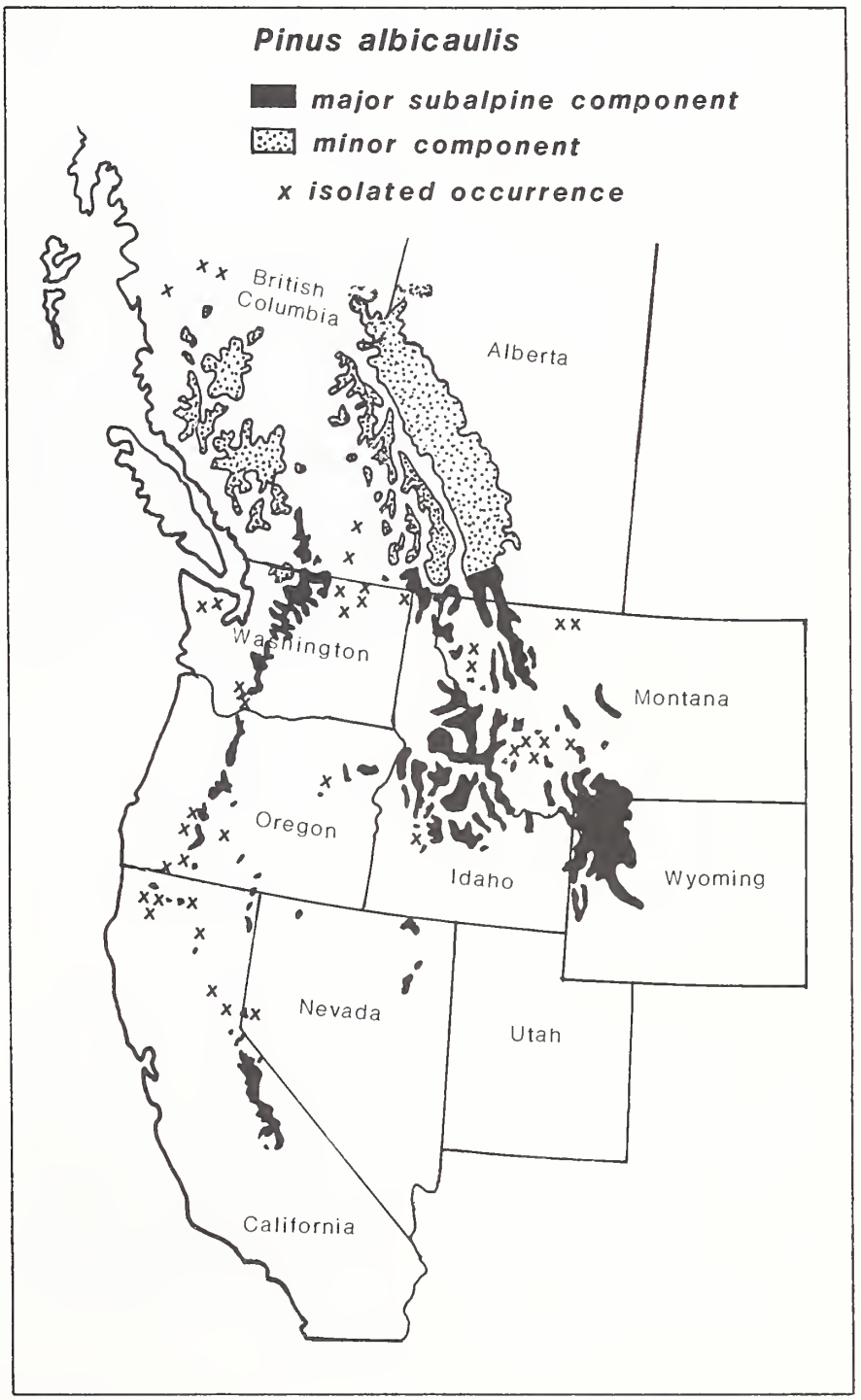
by Frances Reynolds
Intermountain Station

"The high mountains of the West." The phrase conjures picturesque images. An ancient pine clings resolutely to a windswept ridge at timberline. A grizzly bursts from the forest cover at a meadow's edge. A squirrel busily caches seeds for the coming winter.

These scenes so loved by nature photographers are threatened by a dramatic change in the high-mountain ecosystem. "It's the most major change in an ecosystem I can think of", says Dick Krebill, Assistant Station Director at the Intermountain Research Station (INT). "It's making a long-lasting change, maybe for thousands of years."

At the center of concern is the whitebark pine (*Pinus albicaulis*), a hardy and beautiful tree that grows in the highest elevation forest and at timberline. Until recently, it received little scientific attention because it has little value as a commercial timber species. The importance of the whitebark pine in the high mountain ecosystem is only now becoming understood—and with this understanding comes increasing alarm.

In significant portions of its range, whitebark pine populations are declining so rapidly that the ability of the tree to regenerate itself is in question. Population loss threatens not only the species, but the whole high-mountain ecosystem. INT scientists are working to learn more about the whitebark pine and how it might be managed to aid regeneration.



Natural distribution of whitebark pine.

Hardiest of trees

The range of the whitebark pine extends from central California and western Wyoming north to British Columbia and Alberta. The species occupies 10 to 15 percent of the forested landscape in the Rocky Mountains of Montana, Idaho, and northwestern Wyoming. Although it grows over a large geographic area, it is restricted to a fairly narrow ecological zone characterized by high elevation and a cold, windy, snowy, and generally moist climate. Strong winds, thunderstorms, and severe blizzards are common in whitebark pine habitats. Because of the harsh conditions, it grows and matures very slowly.

Whitebark pine has many values in the high-mountain ecosystem. It helps stabilize snow, soil, and rocks on steep terrain. It provides hiding and thermal cover at high elevations where few if any other trees grow. Blue grouse feed and roost in whitebark pine crowns much of the year. It grows in exposed sites where it modifies the climate, allowing less hardy vegetation to establish. The openess of whitebark pine stands provides conditions for abundant wildlife forage.

Most significantly, the tree produces large, oil-rich seeds that are a preferred high-energy food source for a variety of birds and mammals inhabiting a harsh environment. The seeds have also been a food source for Native Americans, who ground them into a nutritious flour. Recently, research has demonstrated the particular importance of the whitebark pine seeds to Clark's nutcrackers, red squirrels, and bears.

Pure stand of mature whitebark pine at an elevation of 8,400 feet in western Montana.

Mutual relationships

Whitebark pine seeds are a preferred food of Clark's nutcrackers, which in turn are responsible for most seed dispersal and regeneration. The birds attack the ripening cones in August, September, and October, opening them with their long, pointed bills and extracting the seeds. Holding up to 150 seeds at a time in a sub-lingual pouch (a sac-like extension of the floor of the mouth), they transport the seeds to exposed sites where they bury them in small caches of a few seeds each. The seed stores, which will keep a year or longer, are recovered in winter and spring months when other foods are scarce; they are also fed to nestlings and fledglings.

The nutcrackers bury many more seeds than they recover. Because the caches are generally on exposed sites suitable for whitebark pine establishment, the seeds germinate and produce more trees. The birds cache seeds up to 14 miles from a seed source. In this way, whitebark pine has become established on sites remote from seed sources, including alpine ridges and large burned or clearcut areas.

Competing with the nutcrackers to harvest the cone crop are red squirrels, the most efficient whitebark pine seed predators. In mixed stands of spruce, fir, and whitebark pine, squirrels harvest the majority of the cone crop, quickly cutting the cones from trees and caching them in large middens on the forest floor. Red squirrels concentrate their foraging on whitebark pine seeds when available, virtually ignoring other foods. In stands having a high whitebark pine component, cone production directly affects annual squirrel population density.

Whitebark pine seeds cached in squirrel middens support other populations as well. For grizzlies and black bears, the seeds raided from middens are an important autumn food. According to Kate Kendall, a research biologist with the National Park Service, in years when a good cone crop makes seeds available, grizzlies in Yellowstone feed exclusively on them in autumn. Caches raked open in the spring provide a high-energy food after hibernation.

Recent research by the Interagency Grizzly Bear Study Team indicates that the availability of seeds influences annual feeding strategies and rates of movement of grizzlies. Cone crops have been correlated with cub production and early weaning. Years of low seed production generally result in greater numbers of management actions and mortalities as bears seek alternate food sources, often in association with human activity.

A shocking decline

All that is being learned about the importance of the whitebark pine to wildlife serves to underscore the concern about its decline. "Shocked" is the way Kate Kendall described her reaction upon learning that 90 percent of the whitebark pines on the eastern side of Glacier National Park are dead or dying. In the Whitefish Range in Montana, one-half to two-thirds of the trees have been lost in the last 10 years. In the Flathead National Forest, 225,000 acres of whitebark pine have suffered some mortality since 1975. Along the Selkirk Crest in northern Idaho, 90 percent of the whitebark pine were dead by the early 1980's.

"This is a tremendous threat and a very complex problem," says Steve Arno, an INT research forester. "To sustain the whitebark pine's value as a food source you have to maintain the population, but it grows and matures so slowly that it's especially slow to recover from damage, and slow to respond to management measures."

Whitebark pine also grows in stunted or krummholz (shrublike) form on windswept ridgetops where little snow accumulates. The wind-battered upper branches are called "flags".

The triple threat

According to Arno, the extent of damage and mortality in many parts of the whitebark pine's range is still unknown. Part of the difficulty in assessing population decline is that three major factors are involved: white pine blister rust, mountain pine beetle epidemics, and fire suppression.

Whitebark pine is highly susceptible to white pine blister rust, a disease introduced into North America from Europe in 1910. It is a major cause of mortality in areas humid enough to permit the spread of spores. Ray Hoff, an INT plant geneticist who has studied blister rust extensively, says that in just 13 years after the disease was introduced, it had become established throughout most of the range of the whitebark pine.

Blister rust mortality has been extensive in the moist mountain regions of northwestern Montana, northern Idaho, and the Washington Cascades. In some stands nearly all the mature trees have been killed. The mortality observed by Kendall in Glacier National Park was caused by blister rust, and it killed the trees along the Selkirk Crest. Significant mortality has occurred in Washington and Oregon but the extent is unknown. In drier areas such as Yellowstone National Park, blister rust has not yet caused appreciable damage.

Periodic epidemics of mountain pine beetles are also a serious problem in much of the whitebark pine's range. The insects usually kill only the larger whitebark pine trees because these trees have an inner bark layer (phloem) thick enough for the larvae to inhabit. A large proportion of the mature whitebark pine in the Northern Rockies was killed by this insect between 1909 and 1940, and a recent epidemic in Montana has killed most of the mature trees in some areas. According to Dale Bartos of INT's mountain pine beetle research unit, a recent survey of beetle damage in the Gallatin and Flathead National Forests and Yellowstone National Park shows that 22 to 44 percent of the population has been killed in the recent past. The mortality in the Whitefish Range is also largely due to mountain pine beetles.

Mountain pine beetle epidemics appear to spread upward into whitebark pine zones from lodgepole pine forests at lower elevations. This is one reason scientists are concerned about a third threat: fire suppression. Fire suppression since the early 1900's has resulted in the development of extensive areas of old lodgepole pine susceptible to severe epidemics.

Fire suppression has had other damaging consequences. Whitebark pine is the potential climax species at alpine timberline and on dry sites, but in subalpine forests it is a seral species that can be replaced by more shade-tolerant conifers. Periodic surface or ground fires help perpetuate moderately fire-resistant whitebark pine by killing its competitor, subalpine fir, and creating small openings where whitebark pine can regenerate. Severe, stand-replacing fires also favor whitebark pine because the tree is regenerated from nutcracker caches in the exposed mineral soil of burns. Shade-tolerant competitors are less hardy on these sites, and because their seeds are windborne, they are less likely to reach areas within burns.

Arno has studied fire history in whitebark pine communities. "Before the early 1900's, fires occurred at mean intervals ranging from 50 to 300 years in different areas. Although data are sketchy, apparently less than one-half of 1 percent of the seral whitebark pine type has burned in the last 15 years. At this rate, the current fire interval is about 3,000 years." In the absence of fire, he says, whitebark pine communities age and become more susceptible to epidemics and disease, and fir and spruce crowd out whitebark pine in subalpine stands.

The implications of widespread loss of the whitebark pine are manifold. It could limit efforts to restore grizzly bears in areas where whitebark pine seeds have been an important food. Lower bear populations could result in a decline in elk predation. Red squirrel populations may diminish with reductions in cone crops (squirrels, in turn, are another prey of bears). Nutcrackers, the primary agent of seed dispersal, may no longer be attracted to stands with little cone production. Small cone crops may be entirely consumed by animals, with no excess seeds left unrecovered in caches to germinate. Whitebark pine loss could result in local extinctions of the species and loss of genetic diversity.

The challenge: what can we do?

Scientists such as Arno, Hoff, and Bartos have learned much about the threats to the whitebark pine. INT scientists are also working on ways to restore and maintain populations.

Since 1964, Hoff has worked on developing western white pine resistant to blister rust. Experiments examining the resistance of other white pines suggested that the resistance of whitebark pine can be increased substantially. Hoff plans to use techniques developed in previous research to produce resistant seedlings. "For areas of moderate hazard, pruning and excising of cankers is a viable option," he says. "In areas of high mortality, resistance is the only option."

Red squirrels concentrate their foraging on whitebark pine seeds when available, virtually ignoring other foods.

INT research cooperator Bob Keane recently adapted the FIRESUM ecological process model to simulate effects of long-term successional trends on whitebark pine communities in relation to fires, fire suppression, and insect and disease epidemics. "In regions where whitebark pine is declining, large areas will have to be rejuvenated in the next few decades if whitebark pine communities are to remain as a major high-elevation forest type," Arno says. "Because it takes nearly a century for seedlings to develop into mature, cone-bearing trees, we're going to have to take a long-term view." Modeling effects of different factors will help in developing management strategies for maintaining vigorous populations.

Arno believes that fire will have to be a major means of regeneration, particularly since clearcutting is inappropriate in most whitebark pine habitat. "We need a lot more information on fuels, burning conditions, fire behavior, and regeneration requirements to use as a basis for silvicultural applications of prescribed fire. Allowing selected lightning ignitions to burn would be a positive first step, but it probably won't be enough." Future research may enable land managers to apply precribed fires designed to favor regeneration of whitebark pine and mortality of competing conifers.

Ward McCaughey of INT's subalpine silviculture research unit is studying predator and site factors affecting the establishment of whitebark pine. This work will lead to the development of methods for natural and artificial regeneration of the species.

Concern over the future of the whitebark pine ecosystem has stimulated the scientific community. A symposium held in March, sponsored by the Forest Service and other concerned agencies, brought scientists from many disciplines together to share knowledge and discuss research needs. Nine INT scientists presented papers and participated in panel discussions. The symposium attracted scientists from Europe and Canada. Land managers attended, too, and are getting involved. John Mumma, Regional Forester for the Northern Region, stated that "it is a challenge to resource managers and researchers to provide the understanding and management alternatives that are needed to produce the values, products, and maintain the environmental quality of these ecosystems". There isn't any time to lose.

If you would like more information, contact Steve Arno at the Intermountain Research Station's Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807. Telephone (406) 329–4800; FTS 584–4800.

Ponderosa pine regeneration: the latest scoop

by Rick Fletcher
Rocky Mountain Station

With a little luck and a proper prescription, these seedlings of natural regeneration will survive to see another growing season.

Forests have the distinction of being a renewable natural resource. What makes this renewal possible is the process of regeneration. Whether natural or by planting of seedlings, regeneration is usually a critical part of any forest management plan.

In no place is regeneration more important than the semi-arid ponderosa pine (*Pinus ponderosa*) forests of western North America. Managers of these commercially valuable forests have traditionally had a tough time with regeneration, due to a host of obstacles.

Scientists with the Rocky Mountain Station's Forestry Sciences Laboratory in Flagstaff, Arizona, are part of a growing effort to provide land managers specific information that will enable them to improve their regeneration decisions and practices. Although ponderosa pine, and specifically regeneration of the tree, have been studied at the lab for many years, it's just within the last decade or so that some very significant findings and successes have surfaced. Even though their research has focused primarily on the Southwest, their findings should be applicable to ponderosa pine throughout most, if not all, its range.

Obstacles to regeneration

Plant physiologist LeRoy (Pat) J. Heidmann says, "Regenerating ponderosa pine in the western United States is tough. The primary barrier throughout its natural range is drought. Annual precipitation in this part of the country is generally adequate for tree growth, but erratic distribution during the year makes seedling establishment difficult. Drought, coupled with competition from various herbaceous species, primarily perennial grasses, effectively lowers soil water potential to a point where pine seedlings have difficulty extracting moisture from the soil," he said.

Regeneration problems are also closely related to soil type. On volcanic soils, seed germination is usually adequate, but seedlings at the end of the first summer growing season are typically very small (3-5 cm tall). Small seedlings are highly susceptible to frost heaving—a freezing/thawing process that actually lifts the seedling out of the ground. On these basalt derived soils, moisture becomes limiting when soil moisture content (SMC) drops below 10 percent. Sedimentary soils, in contrast, are much coarser in texture, and moisture does not become a factor until SMC drops below 1.5 percent.

"One important finding," says Heidmann, "is that seedlings CAN endure severe soil moisture stress and recover. Seedlings appear able to 'shut down' physiologically during periods of moisture stress and resume physiological activity when soil moisture is replenished. Some of our recent studies show that ponderosa pine seedlings, grown for 134 days without watering, have very low transpiration and stomatal conductance rates, but after rewatering, have recovered rapidly."

Competing vegetation can also hamper regeneration. The most severe competitors in the Southwest are spring-growing bunchgrasses. They have an extensive root system that robs moisture from the upper soil layers at the expense of tree seedlings. In other parts of its range, particularly the Pacific Northwest, and throughout much of the Intermountain region, brush is a serious problem.

In addition to these hazards, regeneration is often hampered by winds—common throughout much of the ponderosa pine range. At, or shortly after, tree planting in the spring, plantation sites are subjected to warm days, very low humidities, little or no precipitation, and strong winds. Under these conditions, especially if site preparation is inadequate or lacking, tree seedlings desiccate very quickly.

Heavy grass cover, such as this Arizona fescue, can hamper regeneration by robbing the seedlings of soil moisture.

Finally, seedling growth and survival can be hampered by a host of insects, birds, mammals, and other biotic factors. The greatest of these threats comes from domestic livestock and browsing big game. If they are allowed to graze newly established regeneration areas, no amount of prior planning, in most instances, can save the reforestation project. Smaller mammals, such as gophers and rabbits, often chew on the new seedlings; and mice and squirrels can consume vast amounts of seed and cones.

What to do, what to do?

"Despite these many adverse factors," says Heidmann, "take heart. By following some well-defined guidelines, most land managers will find that ponderosa pine CAN be regenerated, both naturally and artificially."

When regenerating by planting seedlings, one of the first and most important considerations is the seed source. Seedlings should be raised from seed collected in the zone where they are to be planted. Seed should be collected from trees of good form and vigor, free from insects and disease. Growth traits as well as susceptiblity to insects and disease are proving to be hereditary.

Disking is one method of preparing a site for natural regeneration.

Natural regeneration on the Apache-Sitgreaves National Forest in Arizona.

One factor important to plantation success is seedling size. Studies show that planting success with ponderosa pine is inversely related to seedling size. In 1984, Heidmann found that bare-root seedlings less than 11 cm high and 3.65 mm in diameter had a survival rate of over 90 percent. Seedlings from another study, raised at the same nursery and planted within the same enclosure, but with heights and diameters 28 and 34 percent greater, had an overall survival of 13 percent. "What we learned," said Heidmann, "was that the smaller trees were grown at a very high density in the seed beds. Root systems were fibrous with many fine root hairs. The larger trees were grown at about one-third the density in the seedbed, and although larger, had less vigorous root systems. Larger planting stock does not mean better survival," he said. Scientists believe that the poorer survival of larger seedlings is due to greater transpiring surfaces in relation to the root's surface area and its ability to absorb moisture from the soil. There appears to be a dynamic balance between the demand for water by the crown of a seedling, and the ability of the transporting tissue to conduct it.

Besides the size of the seedlings, Heidmann says that a major factor in raising planting stock is the lifting date. Seedlings need to be lifted at a time when they will be in the best physiological condition to grow the maximum number of new roots. Heidmann's studies on six National Forests in Arizona and New Mexico show that the later seedlings were lifted, the higher the field survival.

Survival a year after planting of seedlings lifted March 1 averaged about 94 percent, compared to 58 percent for trees lifted November 1.

Lifted seedlings need to be properly stored and transported to the planting site. At the nursery and at the final destination, they should be stored in refrigerated buildings at slightly above 0 degrees C. Trees should be transported to the delivery site in refrigerated trucks, but not stored there, as refrigeration systems in semi-trucks can break down. "Most important, seedlings should be handled as little as possible," says Heidmann.

Site preparation

Site preparation is crucial for successful regeneration. Station scientists have found that, when competing vegetation is controlled in regeneration areas, the survival rate rises dramatically. In one study on a site occupied by Arizona fescue and mountain muhly, seedling survival 1 year after planting was as high as 99 percent when surrounding grasses were killed with dalapon. Heidmann explains, "We believe this is attributed to the dead grass serving as a mulch, thus conserving soil moisture by reducing evaporation. In an earlier study, we found that soil moisture for the top 0-20 cm soil depth was more than twice as high under grass killed with herbicide as under live grass."

Seedlings have a better chance of surviving when site preparation is initiated as soon as possible after logging or wildfire. Ponderosa pine seedlings may survive competition from grasses if planted concurrently with seeding of grasses. Survival may decrease 30 percent or more for each year's delay in planting.

There are four primary methods for preparing planting sites—chemical, mechanical, prescribed burning, and combinations of these. Herbicides are often ideally suited for use on areas occupied by dense stands of grass. However, extreme caution should be taken to ensure that they are not carried off the site and into drainages, and eventually into potable water. Federal and/or state laws limiting or prohibiting the use of herbicides should always be followed.

Mechanical methods such as disking have proved to be effective in preparing regeneration sites, but dozers or blades should not be used because they may remove valuable top soil. Use caution with heavy equipment, as it can compact the soil, leading to the acceleration of frost heaving.

Fire alone is not an effective site preparation tool—at least in the Southwest. Unless the fire is very hot, not enough of the vegetation is killed. Fire does have a place in preparing planting sites when used in combination with other methods such as herbicides. Fire not only can remove debris, making access to the planting site easier, but it also releases nutrients that promote seedling growth.

Planting

Seedlings may be planted successfully by several methods using either hand tools or power equipment. "The primary objective of planting is to return the seedling to the soil with as little disturbance and distortion of the root system as possible," says Heidmann. "The shorter the period of time from lifting to planting, the better. Throughout this period, seedlings need to be kept cool and moist, and subjected to a minimum of handling," he said.

When planting seedlings by hand, the following guidelines should be considered:

1) Select the planting spot carefully. Seedlings should not be planted in depressions that may eventually be under water. Ponderosa pine does not tolerate excessive moisture. Creating a small basin around the seedling to trap water, however, is encouraged.
2) Scrape away surface litter and dry soil before making the hole or slit.
3) Make the hole deeper than the length of the root system.
4) Place the seedling into the hole with roots extended to the bottom. Fill the hole loosely with soil.
5) Pull seedling up toward the soil surface so that the root collar is about level with the soil surface. It is better to have the seedling planted slightly deeper than normal than too high. Pack soil around seedling with the heel.

One of the biggest errors in tree planting is in not packing the soil tightly around the roots. Roots must be in contact with the soil for absorption of water.

The final consideration in planting is protection from browsing mammals—a crucial point often neglected. Cattle should be excluded for several years. Fences may be necessary. Regular barbed wire fences, however, will not deter deer or elk, which can only be kept out by higher wire fencing. If browsing by wildlife is a particular problem, it may be necessary to place protectors around each individual seedling—an expensive procedure not always successful because they are often knocked over by animals, or outgrown by seedlings during the growing season. Small mammals such as gophers and mice can be poisoned using zinc phosphide or strychnine. Again, remember to adhere to all application guidelines.

Natural regeneration

Successful natural regeneration in the Southwest was virtually unheard of until 1968. It was then that Station scientists, in cooperation with the Chevelon Ranger District, Apache-Sitgreaves National Forest in Arizona, conducted a pilot study to determine if natural regeneration was even feasible. By carefully following their "homemade" prescription, results were very promising. Heidmann and his associates explain that their success involves five critical "ingredients".

These ponderosa pine containerized seedlings are being raised by the Navajo tribe in Arizona in preparation for planting.

1) Monitor the stand to determine prospects for a cone crop that will produce an adequate amount of seed;
2) Census the rodent population and take control measures if necessary;
3) Mark the area for logging, leaving at least five seed trees per acre having a d.b.h. of about 51 cm;
4) Mechanically prepare sites with a large disk in the fall before seed dispersal; and
5) Exclude domestic livestock for at least 5 years.

To date, over 4,450 ha (11,000 acres) have been regenerated successfully on the Chevelon District by following these procedures.

"In order for natural regeneration to succeed, there must be an adequate cone crop," says Heidmann. "Our success occurred in stands with an estimated seedfall of 247,000 seeds/ha (100,000 seeds/acre). Prescriptions call for 12.4 seed trees/ha (5/acre); however, numerous smaller pole-size trees, which produce seed, were also left. It is better to plan for an excess of seed than not enough because large amounts of seed can be lost to insects, mice, and squirrels," he says—which brings up the problem of rodents. They can consume vast amounts of seed and can effectively prevent successful regeneration efforts. One of the most important

steps in obtaining natural regeneration is to determine the rodent pressure, and take control measures if necessary. A rodent census should be taken in the fall of the year prior to seedfall. Traps should be placed on the regeneration site for three successive nights. If 13 mammals are caught per 100 traps, control measures should be taken using an approved rodenticide. On the Chevelon District, scientists used zinc phosphide on oats, (0.91 kg (2 lb.) per 45.36 kg (100 lb.) of grain). The area should be checked again the following fall, and if 13 or more rodents are still taken per 100 traps, the area should be poisoned again.

Site preparation and protection

In the fall, before seed fall, sites should be prepared using a large disk with 96 cm (38 in.) blades, drawing it over the site in a criss-cross pattern so that about 70 percent of the site is prepared. If possible, cattle should be excluded from the regeneration area for at least five years, but grazing may be allowed after three years. If cattle are allowed on natural regeneration areas, use should be restricted to the growing season, and then only under careful supervision. Only small numbers of cattle should be allowed on the site for short periods of time.

Planting seedlings on the Coconino National Forest in northern Arizona.

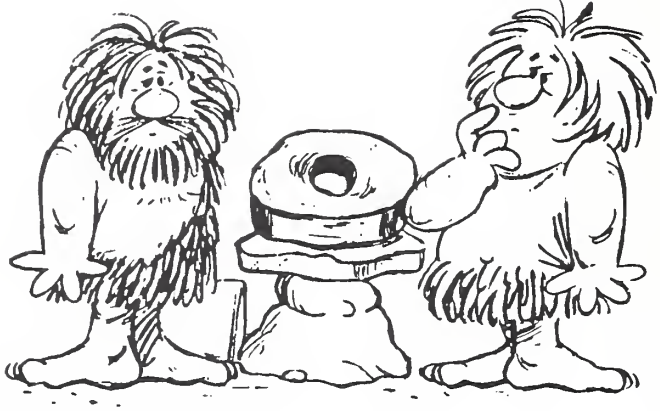
By following these procedures, thousands of hectares of natural regeneration have been established in the Southwest, at a cost of about 16 percent of that for planting.

While ponderosa pine may not be the easiest tree species to regenerate, land managers no longer need to shy away from attempting it. By following these guidelines, drought, short growing seasons, rodents, insects, browsing, vegetative competition, and other deterrents no longer need to be the looming obstacles that they once were.

If you would like additional information on these and related studies, contact Pat Heidmann at the Rocky Mountain Station's Forestry Sciences Laboratory, 700 Knoles Drive, Flagstaff, Arizona 86001, (602) 527–7315, FTS–765–7315.

Further details are also provided in the reprint titled *Regeneration Strategies for Ponderosa Pine*, available from the Rocky Mountain Station.

New from research



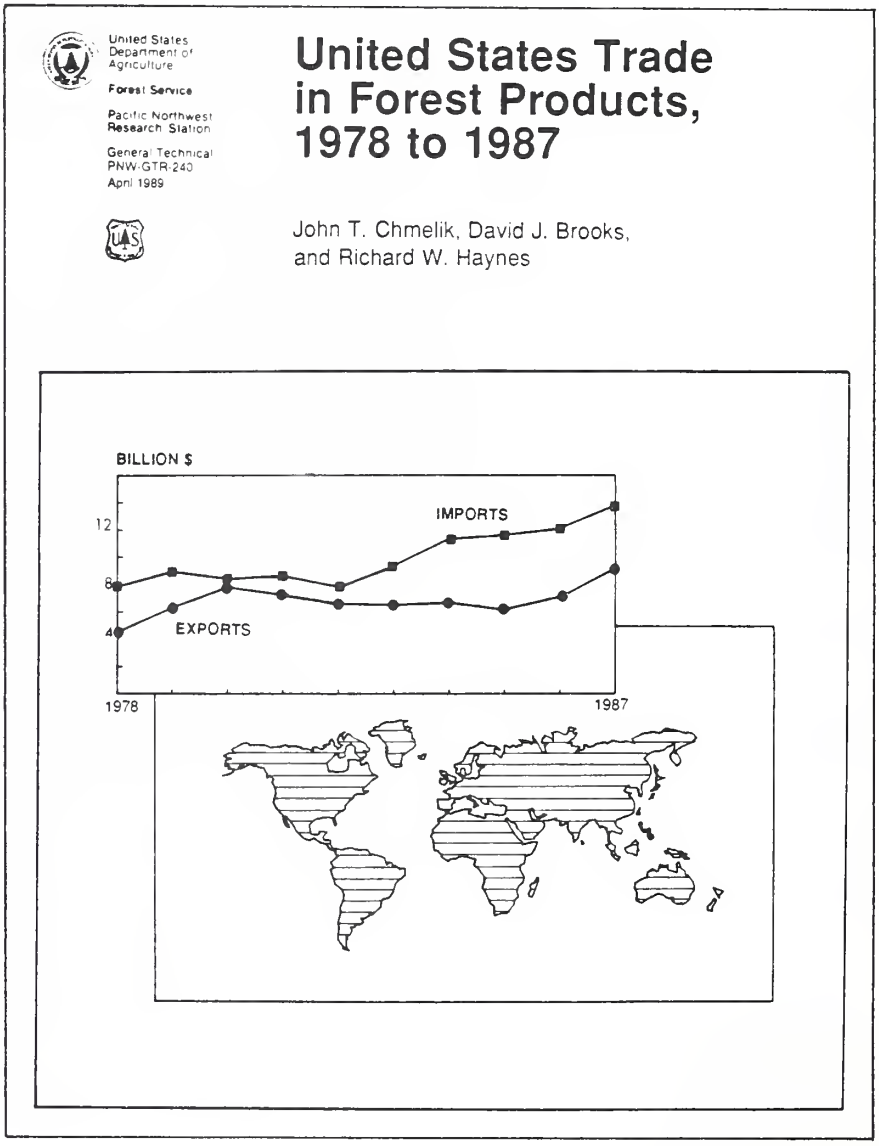
United States forest products trade for 1978–87 summarized

The United States is the world's leading producer and consumer of forest products. The country is also the world's leading importer of forest products, and is second only to Canada as an exporter of these products. These are some of the facts presented in General Technical Report PNW-240.

The authors summarize trade based on U.S. Department of Commerce records with groupings into 10 regions, some of which are individual countries. Tables summarize volume and unit values. Import and export data are shown for 18 groups of commodities aggregated from 800 individual commodity items. The data for each commodity include detail on trading partners and information on shipments through four regional aggregations of U.S. Customs Service Districts.

The summary includes highlights of imports, exports, net trade, and trade by ocean basin. In 1987, for instance, U.S. imports of forest products increased more than 75 percent from 1978, with Canada dominating U.S. imports. Exports increased more than 100 percent between 1978 and 1987. In constant dollars, the forest products trade deficit was slightly lower in 1987 than in 1978. The pattern of forest products trade during this period was influenced by the exchange value of the U.S. dollar and economic activity in the United States and among U.S. trading partners.

Request, *United States Trade in Forest Products, 1978 to 1987*, General Technical Report PNW-240, from the Pacific Northwest Research Station.

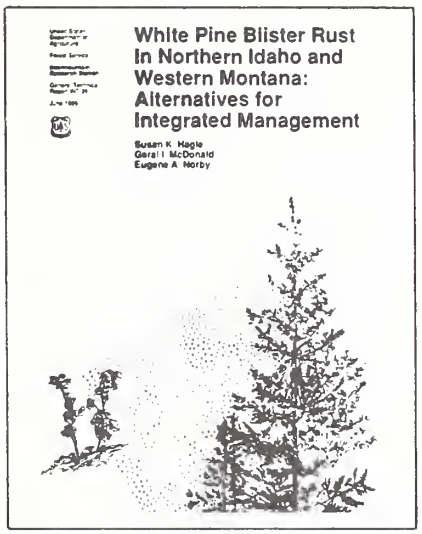


Guide enables integrated management of white pine blister rust

Western white pine, once the most sought after conifer species in the western United States, is so highly susceptible to white pine blister rust that mortality rates of 90 percent or more have been recorded in what were once vigorous, well-stocked stands. A new publication, available from the Intermountain Research Station, summarizes the effects of the disease on western white pine since its introduction from Europe in 1910, and presents current technology for managing stands in Idaho and Montana.

The guide describes four major goals for western white pine management: (1) reduce probability of infection, (2) reduce mortality following infection, (3) maintain genetic diversity for silvical characteristics in addition to rust resistance, and (4) minimize selection pressure on the rust. To achieve these goals, it provides site-specific management alternatives using a dichotomous key, allowing land managers to determine which alternatives are operationally and economically viable for individual situations.

Supplementary appendixes discuss western white pine silvics, explain the concept of rust hazard and its application to stand management, and describe approaches using rust resistance and intermediate stand treatments.



Request *White Pine Blister Rust in Northern Idaho and Western Montana: Alternatives for Integrated Management*, General Technical Report INT-261.

A new way to measure campsite impacts

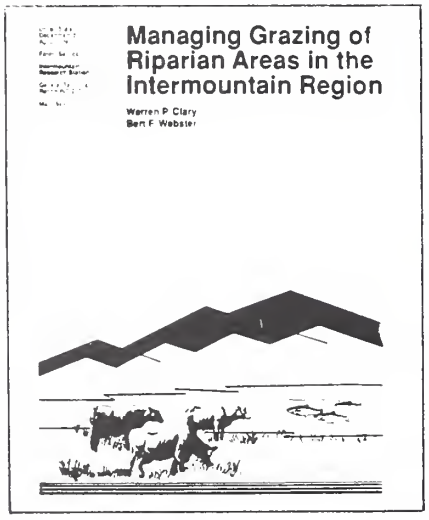
Loss of vegetation is one of the most frequently described effects of camping, but techniques to measure it have been inadequate. A new index of vegetation impact incorporates two essential expressions of vegetation loss: the proportion of vegetation lost and the areal extent of vegetation loss.

Research Note INT-389, *Area of Vegetation Loss: A New Index of Campsite Impact*, describes the new index—called area of vegetation loss—and uses it to reinterpret previously reported data on vegetation impact on campsites. Vegetation loss is discussed in relation to amount of use, party type, and environment. Use of the new index confirms the importance of concentrating use on a small number of sites, rather than spreading it over a larger number of sites, and concentrating camping activities on as small a part of the campsite as possible.

Request this publication from the Intermountain Research Station.

Guidance for planning riparian grazing

Improper livestock management, through excessive grazing and trampling, can affect riparian-stream habitats by reducing or eliminating riparian vegetation. Concern about the effect of livestock grazing on riparian-dependent resources has resulted in controversies about the appropriate management approach. General Technical Report INT-263, *Managing Grazing of Riparian Areas in the Intermountain Region*, provides guidance for planning grazing of riparian areas to reduce both nonpoint source pollution and potential grazing impacts on other



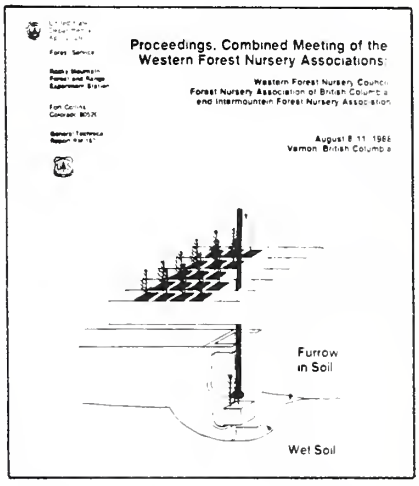
riparian-dependent resources. The recommendations, supported by broadly-based information, should be applicable beyond the Intermountain Region.

The recommendations are general criteria that can be applied to a variety of situations. In addition, initial actions are suggested for different types of stream channels. Three appendixes provide a review of grazing systems, current information on grazing riparian areas, and a method of calculating ecological status and resource value ratings in riparian areas.

Contact the Intermountain Research Station to obtain a copy of this publication.

Discussing forest nursery management

On August 8–11, 1988 a meeting of the Western Forest Nursery Associations was held in Vernon, British Columbia. Forty two papers were presented on various aspects of forest nursery management. Specific topics included container seedling culture, nursery management, seedling quality, nursery pests, nursery equipment, and outplanting performance. Articles demanding special attention were those on new technology of container-bareroot transplants.



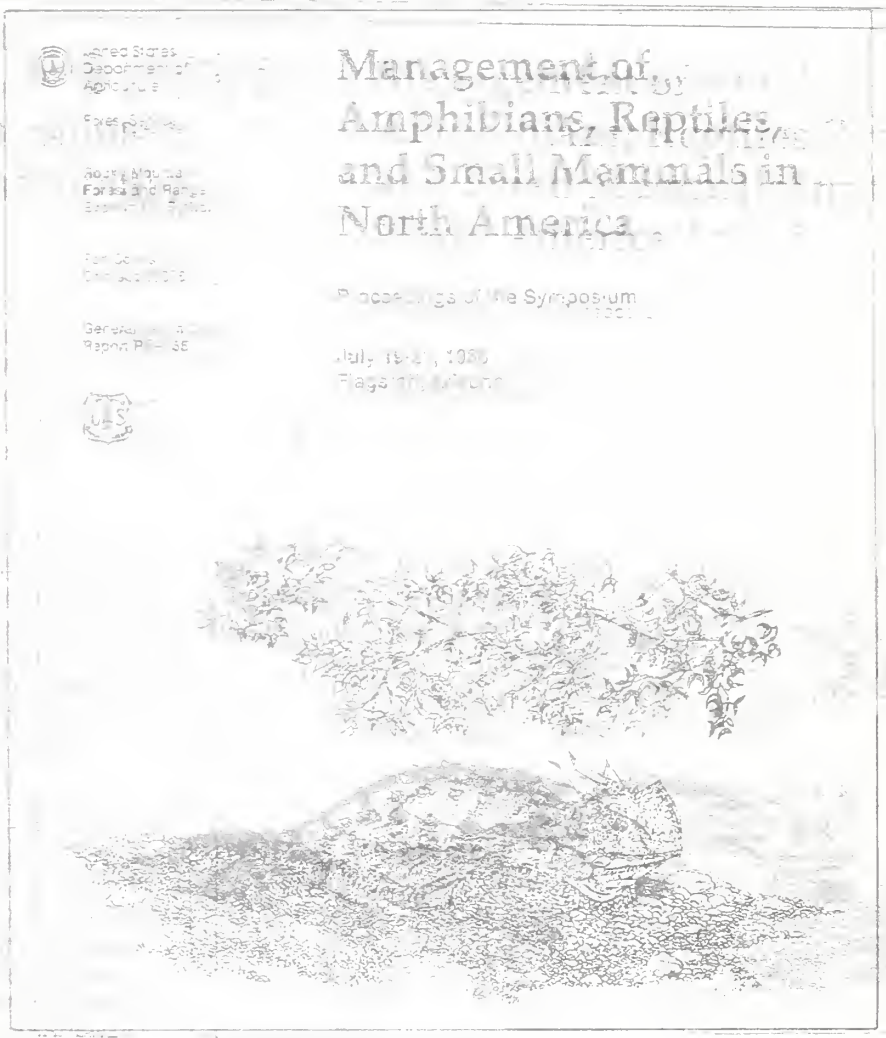
For your copy of *Proceedings, Combined Meeting of the Western Forest Nursery Associations*, General Technical Report RM-167, contact the Rocky Mountain Station.

Proceedings published on amphibians, reptiles, and small mammals symposium

Amphibians, reptiles and small mammals are a significant wildlife component in most habitats of North America. They deserve careful consideration from an environmental management and conservation standpoint.

Such was the goal of an intriguing symposium on wildlife management held last year in Flagstaff, Arizona. Several papers were presented on a variety of topics such as prairie dog habitat management of gopher tortoises and the habitat needs of a variety of salamander species.

The symposium was sponsored by the Arizona Game and Fish Department, the Arizona Chapter of the Wildlife Society, Northern Arizona University and the USDA Forest Service. For a copy of the proceedings, contact the Rocky Mountain Station and request *Management of Amphibians, Reptiles, and Small Mammals in North America*. General Technical Report RM-166.



Results synthesized for major study of range management

Research results from an 11-year rangeland research and management project that involved 21 private landowners and 7 State of Oregon and Federal agencies has resulted in increasing application of new range improvement practices by ranchers. The authors of General Technical Report PNW-238 have synthesized the study (which resulted in more than 100 publications and reports) into one document presenting state-of-the-art information for managing rangelands in the interior West, including an understanding of the economic consequences and effects on related resources.

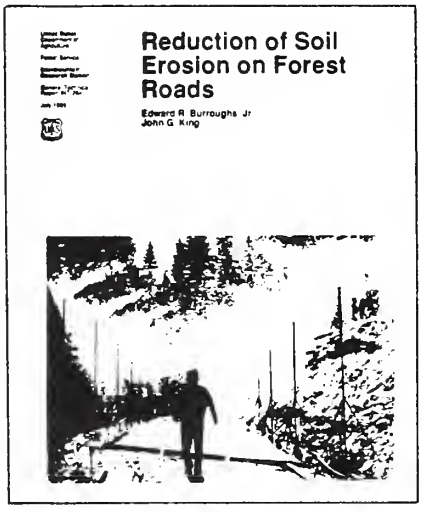
The Oregon Range Evaluation Project (EVAL) resulted after a 1970 review of range resources in the 48 adjacent States. The goal of EVAL was to acquire, develop, assemble, and relate information needed to manage range resources with related resources. The report discusses how the project was developed and implemented.

Many range improvement specifications and costs are also briefly described. Research on herbage and browse responses to management strategies is summarized.

Other topics include effects of management on water and other resources (such as wood production, birds and small mammals, and cultural heritage), determining grazing capacities, economics of management strategies, and a critique of the project.

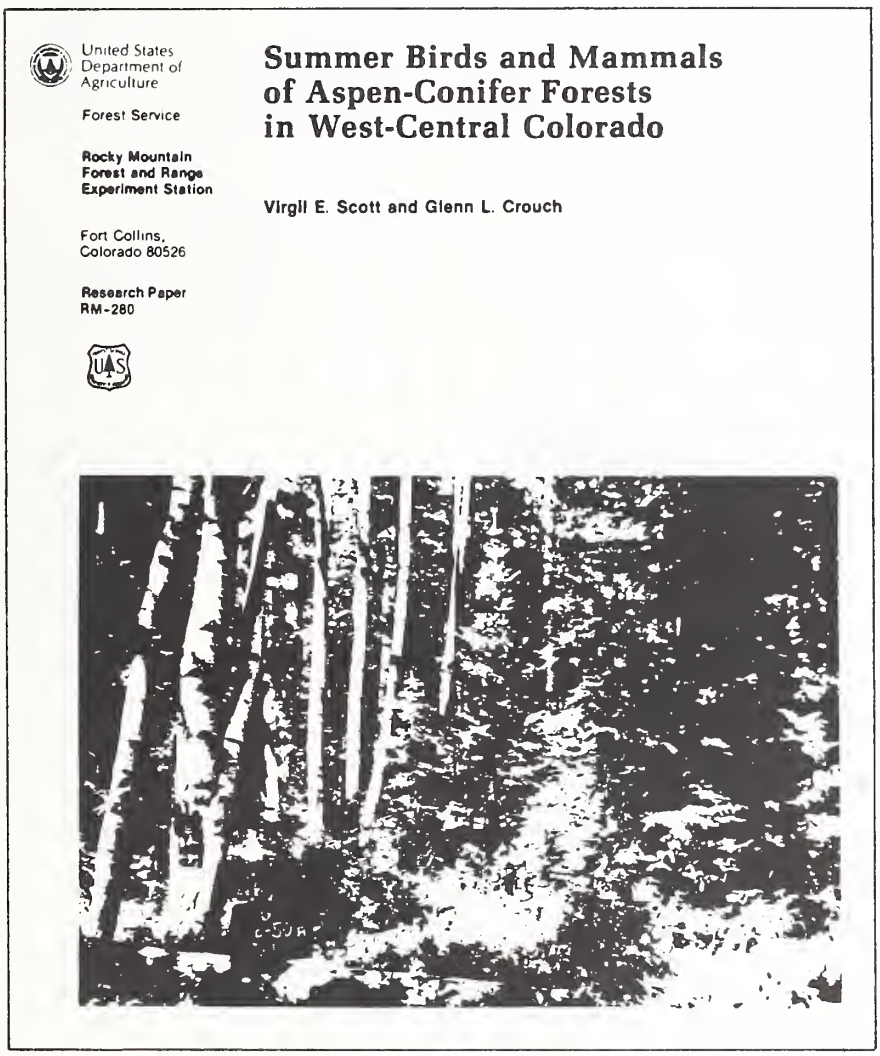
Request *Managing Interior Northwest Rangelands: The Oregon Range Evaluation Project*, General Technical Report PNW-238, from the Pacific Northwest Research Station.

Better ways to reduce soil erosion on forest roads



New information about onsite road sediment, developed by the Intermountain Research Station's Engineering Technology and Watershed Management Research Work Units, will enable land managers to improve estimation of sediment yield from roads. Results of onsite erosion control work from across the United States provide estimates of the amount of erosion reduction on forest roads from various treatments. Supplementary information includes the effects of slope gradient, soil characteristics, and ground cover.

General Technical Report INT-264, *Reduction of Soil Erosion on Forest Roads*, enables land managers to estimate sediment travel below fill slopes, as well as the combined effect of erosion control treatments of the running surface, road cut, and ditch. Copies are available from the Intermountain Research Station.



Study of wildlife in aspen-conifer stands

Aspen and conifer forests are important habitat for wildlife species in the Central Rocky Mountains. A recent publication titled *Summer Birds and Mammals of Aspen-Conifer Forests in West-Central Colorado* inventories eighteen bird species and three small mammals. The research is conducted in pure aspen stands, nearly pure conifer stands, and in stands with a combination of both.

While prevailing opinion suggests that aspen overstories provide better habitat for more species than conifer overstories, the authors find that both types of trees provide equal habitat for birds and mammals. Aspen, however, do support some species that might otherwise be absent.

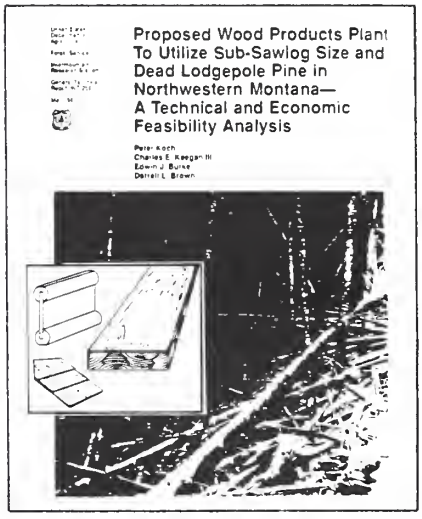
Overall, the study suggests that management practices which maintain a mixture of aspen and conifers appear to be most beneficial to the largest number of wildlife species. For a copy of the report, contact the Rocky Mountain Station and request Research Paper RM-280.

A proposal for economical use of stagnant timber

Large stands of stagnated, bark-beetle infested, and dead timber, primarily lodgepole pine, constitute a major land management problem in northwestern Montana. A wood products plant, proposed in a new Intermountain Research Station publication, promises to solve this problem by removing the timber at minimal public cost while providing significant employment for Montana residents and an appropriate return for investors.

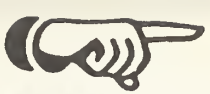
The proposal evaluates the technical and economic feasibility of an integrated multiproduct facility designed to utilize small-diameter (sub-sawtimber size) lodgepole pine.

The manufacturing plant, employing 271 people, would process 200,000 tons (oven-dry weight basis) of stemwood annually. Trees harvested would be predominantly lodgepole pine in diameter classes from 3 to 7 inches.



Several manufacturing centers integrated into the plant would produce fabricated and reconstituted products for uses historically filled by large-diameter, old-growth timber. Three of the plant's products— market oriented-strand board, edge-glued lumber panels for mill work, and fabricated joists—would produce 90 percent of its revenue. The facility would generate an estimated $40 million in revenue in its first year of full production.

To learn more, request *Proposed Wood Products Plant to Utilize Sub-Sawlog Size and Dead Lodgepole Pine in Northwestern Montana — A Technical and Economic Feasibility Analysis*, General Technical Report INT-258.



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3. *Productivity of Forests of the United States and Its Relation to Soil and Site Factors and Management Practices: A Review*, General Technical Report PNW-222.
4. *Forest Habitats and the Nutritional Ecology of Sitka Black-tailed Deer: A Research Synthesis with Implications for Forest Management*, General Technical Report PNW-230.
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3. *Area of Vegetation Loss: A New Index of Campsite Impact*, Research Note INT-389.
4. *Managing Grazing of Riparian Areas in the Intermountain Region*, General Technical Report INT-263.
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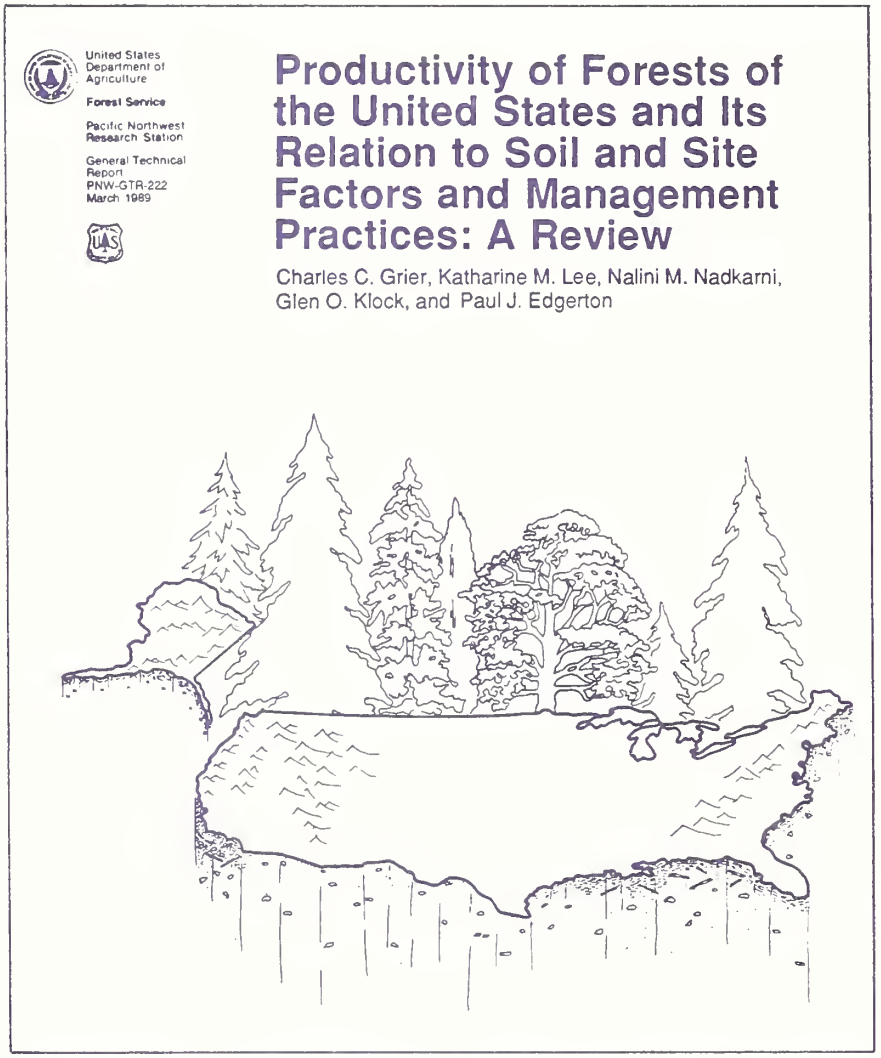
Research on forest productivity reviewed

As forest managers make decisions, a constant concern is how actions will affect forest productivity. Recently, published data on the productivity of major forest regions of the United States were evaluated and synthesized to assess what is known about management impacts on forest productivity.

The authors of General Technical Report PNW-222 studied the scientific literature while using an ecologist's measure of productivity: net primary productivity as the total amount of plant material produced by a forest per unit of area per year. This definition does not express productivity in terms of products, but does allow comparisons among regions and sheds light on factors influencing productivity.

The report provides examples of management practices that can alter potential productivity on a site by changing the physical, chemical, or biological characteristics of the soil. The examples represent a cross section of the kinds of practices that can change potential productivity of a site. The report also offers insight into the direction needed in the future for research on forest productivity.



Request *Productivity of Forests of the United States and Its Relation to Soil and Site Factors and Management Practices: A Review*, General Technical Report PNW-222, from the Pacific Northwest Research Station.

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